EFFECT OF SOME ECOLOGICAL FACTORS ON THE DEVELOPMENT OF DYSDERCUS CINGULATUS FAB.

(HEMIPTERA : PYRRHOCORIDAE)

DISSERTATION
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This is to certify that Mr. Jamil Ahmad has completed his research work entitled "Effect of some ecological factors on the development of Dysdercus cingulatus Fab. (Hemiptera : Pyrrhocoridae)" under my supervision for the degree of Master of Philosophy of the Aligarh Muslim University, Aligarh. This amounts to an original contribution to the existing knowledge of the subject. He is allowed to submit the work for the award of M.Phil. degree in Zoology of the Aligarh Muslim University, Aligarh.

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Reader.

C O N T E N T S

INTRODUCTION

Several species of genus Dysdercus, belong to order Hemiptera and family Pyrrhocoridae have been reported from different parts of the world. These are D. cingulatus Fab., D. koenigii Fab., D. superstitiosus Fab., D. howardi Ballou., D. fasciatus Sign., D. nigrofasciatus Stal., D. sidae Montr. D. delaunayi, D. peruvianus Guerin., D. sanguineosus., D. intermedius, D. cardinalis Gerst., D. melanoderes Karsch. and D. pallidus, etc. The former two species are frequently found in India. They are usually moderate in size and reddish in colour. Dysdercus cingulatus Fab. is cosmopolitan in nature and found in Uttar Pradesh, Bihar, Punjab, Madhya Pradesh, Bombay, Tamil Nadu, West Bengal and in other parts of India (Sohi, 1964). Genus Dysdercus have also been reported as a serious pest of cotton in every cotton growing country with the exception of Egypt, Northern America, Turkestan and Mesopotamia (Whitefield, 1933).

The cotton stainer, Dysdercus cingulatus Fab. commonly known as red cotton bug, is a polyphagous pest, especially it is a serious and major pest of cotton in India. Besides cotton, it is also found at Aligarh actively feeding and copulating on several other Malvaceous plants such as Althea rosea, Abelmoschus esculentus, Sida acuta, Thespesia populnea

and Abutilon indicum, etc., during the months of October to February, as alternative to host plant Gossypium hirsutum. Besides Malvaceous plants, they also attack a number of plants belonging to the families Graminae, Cruciferae and Cucurbitaceae.

The red cotton bug, Dysdercus cingulatus Fab., possesses hemipteroid type of wings and mouth parts. The mouth parts are of piercing and suctorial type. The adults as well as nymphs suck the plant sap, especially from the leaves and green cotton bolls and cause damage to the young growing plants. When the green cotton bolls are exposed, they attack the young seeds and suck the sap. These seeds are damaged and make them unfit for sowing purpose. The salivary secretion of these bugs are very harmful for the developing seeds in the green cotton bolls. This secretion adversely affects the growth of the seeds as it either stops the growth or degenerates the seeds. It has also been reported by Narayanan (1962) that these bugs transmit a microorganism, Nematospora gossypii, into the exposed cotton bolls, which is harmful for human beings.

Extensive studies have not been made on the effects of ecological factors (temperature, relative humidity and

food plants) on the development of Dysdercus cingulatus Fab. Keeping in view its economic importance, an attempt has been made in the present work to assess the influence of different host plants, temperature, relative humidity and density on the fecundity, visibility of eggs, longevity, mortality and development of Dysdercus cingulatus Fab. under laboratory conditions.

REVIEW OF LITERATURE

Biology of Dysdercus cingulatus Fab. has been studied by Pruthi (1923), Mehta (1930) and Srivastava and Bahadur (1958) under the different ecological conditions.

Mehta (1930) has observed that the pre-copulation period varied from 3-9 days between 86°F to 98°F in D. cingulatus Fab. It is extended upto 15 days in the range of 77°F to 87°F and further extended upto 35-36 days at 69°F to 82°F. MacGill (1935) recorded that the pairing occurred in 2-8 days from the date of emergence of females in D. howardi. The copulation period varies along with variation in temperature. It varies in D. cingulatus Fab. from 3 to 5 days at 65°F to 70°F (Mehta, 1930).

Oviposition in the insects belonging to the family Pyrrhocoridae has been studied by different workers. Mehta (1930) observed the female D. cingulatus Fab. to deposit its eggs in the cracks of soft soil. Ballard and Evans (1928) reported in D. sidae to deposit its eggs in one inch deep soil below the surface or under some substratum. Hargreave and Taylor (1937) observed that adult female of D.nigrofasciatus deposits its eggs near to the base of the surrounding plants

or in exposed cotton bolls. Thangavelu (1978) in *D. laetus* (Hemiptera:Lygaeidae) observed adult female deposits its eggs in young and non-dehisced capsules of the host plant. Srivastava and Bahadur (1958) reported that the female of *D. cingulatus* Fab. protrudes the posterior part of its abdomen and inserts its into the soft soil and deposits the eggs in 2-3 hours. Bhatia and Kaul (1966) recorded that the oviposition period is 22.2, 10.2 and 10.4 days at 20°C, 25°C and 30°C respectively in *D. koenigii* Fab.

Mehta (1930) in *D. cingulatus* Fab., Clarke and Sardesai (1959) in *D. fasciatus* Sign. and Mac Gill (1935) in *D. howardi* Ballou., reported that the oviposition is affected by temperature and relative humidity. The extremes of temperature affect the rate of oviposition in *D. koenigii* Fab. Eggs are not laid below 20°C and above 35°C. Bhatia and Kaul (1966) recorded that *D. koenigii* Fab. deposited its eggs at 15°C, but the eggs are less in number than the eggs laid at higher temperatures.

Variation in pre-oviposition and oviposition periods in different species has been observed by different workers. It varies from 7-16 days in *D. nigrofasciatus* (Ullyett, 1930). It varies from 3-6 days at 95°F and 13-20 days at 70°F to 86°F

in D. cingulatus Fab. (Mehta, 1930).

The percentage of hatching of eggs at different levels of temperature and relative humidity has been studied by different workers in different species. Mehta (1930) found high percentage of hatching in D. cingulatus Fab. at 91.4°F and 82-79 per cent R.H. and the incubation period was 5-6 days. The eggs failed to hatch below 35°C in D. fasciatus Sign. (Clarke and Sardesai, 1959). The hatching was maximum (94.0 per cent) at 30°C and 72 per cent R.H. in D. superstitiosus (Vrydagh, 1941) and the incubation period was 4.05 days. Mac Gill (1945) recorded the optimum temperature and relative humidity for the development of eggs of D. howardi Bollou., was approximately 27°C with R.H. 75 per cent. Vrydagh (1941) has reported hundred per cent hatching in D. superstitiosus at 30°C and R.H. 95 per cent and the incubation period decreased from 4.05 to 4 days. Bhatia and Kaul (1966) found that 15°C and 40°C were unsuitable for the development of D. koenigii Fab. Mehta (1930) observed the young nymphs of D. cingulatus Fab. are highly sensitive to high temperatures and humidities.

The longevity of adults D. fasciatus, D. nigrofasciatus and D. superstitiosus has been studied by Hargreave and Taylor (1937). Their males survived for 65, 71, and 91 days

respectively and females survived for 62, 72 and 43 days respectively. Pomeroy and Golding (1923) observed maximum survival of 57 days for males and 47 days for females of D. superstitiosus. Barbosa (1950) observed the longevity of male and female adults of D. nigrofasciatus to be 48.8 days and 33.7 days respectively at 25°C and 100 per cent R.H. Mehta (1930) has reported that temperature and relative humidity affect the longevity of adults of D. cingulatus Fab. and observed maximum longevity to vary from 75-93 days in male and female adults in the range of 55-79°F and R.H. 65 per cent. These adult bugs died within a few days at temperatures above 100°F even when the R.H. was favourable (40-80 per cent). The lethal temperature was 106°F at which the adults died within a few hours, and at temperatures from 90°F - 100°F and R.H. 5-20 per cent, the bugs died within 3-5 days and did not lay eggs during this period.

A particular insect is the pest of a specific host plant. These insect pests have been reported to switch over to other host plants, in the absence of their specific host plant, to get the food supply throughout the year for their survival. Watson (1916) reported that D. delaunayi infests the pods of Eriodendron anfructuosum and Thespesia populnea as alternative to host plant in the absence of Gossypium spp. Cotes (1893) reported that D. cingulatus Fab. feeds

on Lagenaria vulgaris in Kanpur, and on Brassica oleracea in Calcutta. It is also reported that D. koenigii feeds on green pods of H. esculentus (Chatterjee and Raychoudhri, 1960). Singh (1972) observed adults of Dysdercus cingulatus Fab. actively feeding and copulating on Thespesia populnea (L.), tree growing in the horticultural garden of the J.N. Agricultural University, Jabalpur, during the last week of November, 1971. Srivastava and Gupta (1971) recorded Dysdercus cingulatus Fab. as a new pest of wheat. It has been observed and recorded in "Results of cotton cultivation experiments" in Formosa (1936) that Dysdercus cingulatus Fab. causes much damage to Hibiscus and sugarcane and other plants in the absence of cotton plant (Gossypium spp.) in the field. Sohi (1964) recorded that adults and nymphs of Dysdercus cingulatus Fab. survived on different other plants in the field such as Triticum vulgare, Zea mays, Pennisetum typhoideum, Hibiscus rosa-sinensis, Abelmoschus esculentus, Althea roses and Solanum in the absence of cotton (Gossypium spp.)

Geering and Coaker (1960) recorded greater nymphal duration of D. superatitiosus when reared on Sorghum grain as compared with those reared on cotton seeds (Gossypium spp.).

Thangavelu (1978) studied the effect of different food plants on the development rate days and growth rate of *O. laetus* Kirby. He provided *Gossypium hirsutum*, *Abutilon indicum*, *Sida acuta*, *Abelmoschus esculentus*, *Thespesia populnea*, *Hibiscus vitifolius* and *Hibiscus sabdariffa* in place of its host plant and concluded the host preference in the following declining order: *Abutilon indicum*, *Sida acuta*, *Gossypium hirsutum*, *Thespesia populnea*, *Hibiscus sabdariffa*, *Hibiscus vitifolius* and *Abelmoschus esculentus*.

MATERIAL AND METHODS

Adults of Dysdercus cingulatus Fab. were collected from the various host plants such as Abutilon indicum, Thespesia populanea, Gossypium hirsutum, Sida acuta, and Abelmoschus esculentus, etc., from and around the University Campus. These adults were kept in glass jars of two sizes, each measuring 15 cm X 10 cm and 20 cm X 15 cm, covered with muslin cloth and tied with rubber bands (Fig. 1 a & b) for rearing in the laboratory at 30 ± 2°C and 80 ± 5 per cent relative humidity in an Orien incubator (Fig. 2). The insects were fed on Gossypium hirsutum (Cotton bolls) soaked in water on alternate days. Each glass jar was provided with 1.00 cm thick sterilized moist sand layer at the bottom for egg-laying. These jars with eggs were placed at 30 ± 2°C and 80 ± 5 per cent relative humidity in the incubator for hatching. The newly hatched nymphal instars were then transferred into the small glass jars for rearing at the above conditions and the adults emerged from these nymphal instars were transferred into large glass jars and maintained as stock.

In order to study the adults, copulation, pre-oviposition, oviposition, post-oviposition, egg, incubation, nymphal instars, application of Dyar's law to different instars,

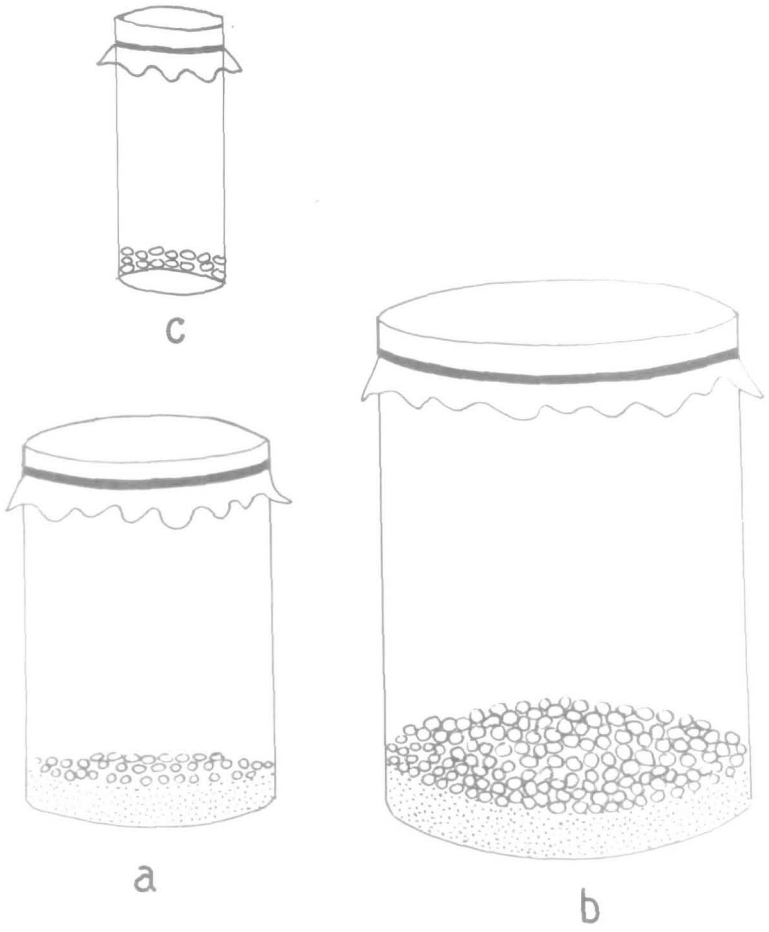
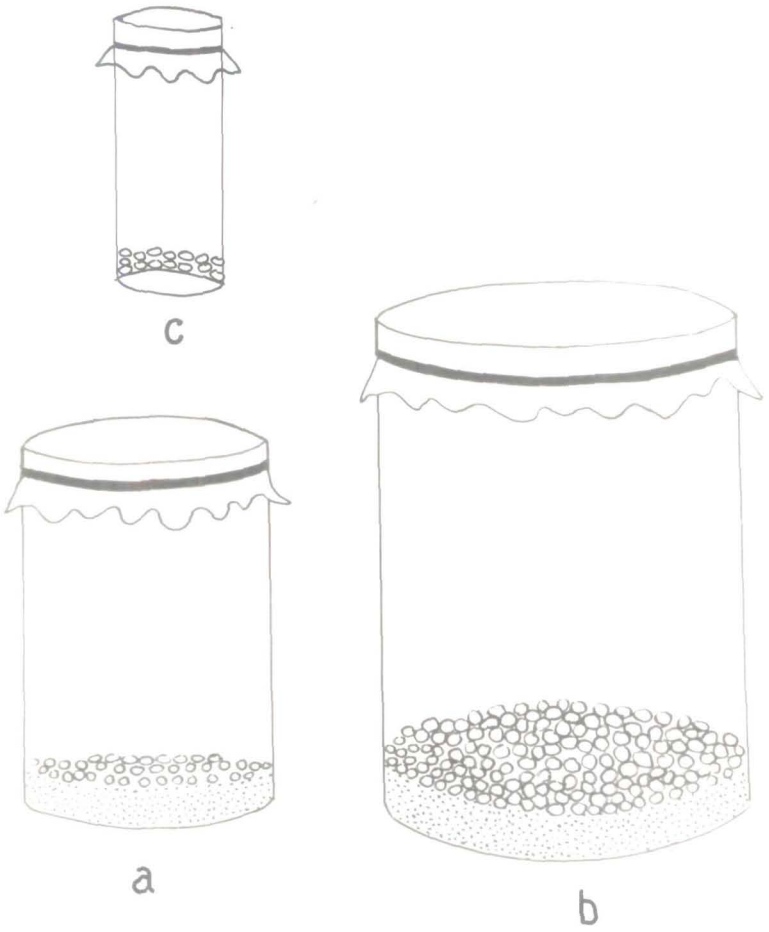


Figure 1. Glass jars and glass tube used for rearing Dysdercus cingulatus Fab.

(a) Glass jar, measuring 15 cm x 10 cm.
(b) Glass jar, measuring 20 cm x 15 cm.
(c) Glass tube, measuring 9 cm x 2 cm.



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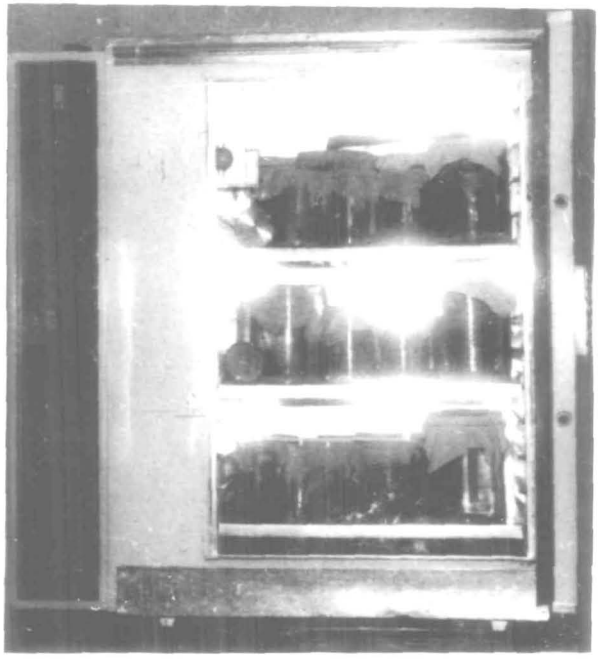

Figure 2. Orien incubator used for rearing Dysdercus cingulatus Fab.

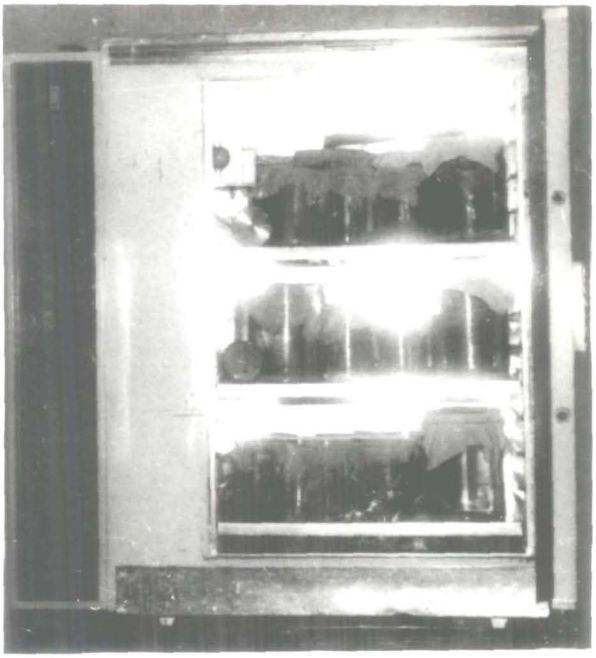

Figure 2. Orien incubator used for rearing *Dysdercus cingulatus* Fab.

sex ratio, survival, effect of different levels of temperature and relative humidity on the incubation period and hatching of eggs, influence of different host plants on nymphal duration, body weight, fecundity, viability of eggs, longevity of adults, effect of crowding stress on the fecundity and viability of eggs, sexual maturation of gonads, number of developing eggs per ovariole, length of egg E_1 and egg E_2, size, and weight of newly emerged and mature adults and fluctuation in body weight of adults till death of D. cingulatus Fab., the following experiments were designed and conducted in the laboratory. The detailed observations have been included under different sub-heading.

(1) Ten pairs of newly emerged adults of D. cingulatus Fab. were obtained from the stock. Each pair was kept separately in glass jars, each measuring 15 cm x 10 cm., provided with 1.00 cm. thick moist sterilised sand at the bottom for oviposition. The jar was covered with muslin cloth, tied with rubber band and kept at 30 ± 2°C and 80 ± 5 per cent relative humidity in an incubator. Cotton bolls soaked in water were supplied on alternate days as food. The observations on adults, copulation, pre-oviposition, oviposition, and post-oviposition periods were recorded. The eggs were placed into petri-dishes, each measuring 10 cm. in diameter, and were

kept in the incubator at 30 ± 2°C and R.H. 80 ± 5 per cent for hatching. The incubation period and number of eggs hatched were recorded.

(2) In order to study the nymphal instar, 30 newly hatched first instar nymphs were reared separately in glass tubes, each measuring 9.0 cm x 2.0 cm. (Fig.1.c), covered with muslin cloth and tied with rubber bands, at 30 ± 2°C and 80 ± 5 per cent R.H. Cotton balls soaked in water were supplied as food on alternate days. The observations on nymphal instars and nymphal duration were recorded. For observations on morphometrics of nymphs and adults, 100 newly hatched first instar nymphs were obtained from the first set of the experiments and reared at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton balls soaked in water. Fresh food was given on alternate days. The observations on the length and width of different body parts of different nymphal instars and adults were recorded. The measurements were made with the help of micrometer under the binocular.

(3) Ten pairs of newly emerged adults were obtained from the stock. Each pair was kept separately in glass jars, each measuring 15 cm x 10 cm., provided with 1.0cm thick moist sterilized sand layer at bottom for oviposition.

The jar was covered with muslin cloth and tied with rubber band . They were fed on cotton bolls soaked in water and reared at 30 ± 2°C and R.H. 80 ± 5 per cent in an incubator. The eggs obtained from each pair were kept at 30 ± 2°C and R.H. 80 ± 5 per cent for hatching. In order to get adults, newly emerged nymphs were reared separately at the above conditions and fed on cotton bolls soaked in water. Fresh food was given on alternate days. The observations on sex ratio and survival of the adults were recorded. The results obtained from the above three experiments are included under the sub-heading of the observation "Development of Dysdercus cingulatus Fab. at constant ecological conditions in the laboratory."

(4) The eggs obtained from the first set of experiments were kept at 40 ± 5, 60 ± 5, 80 ± 5 and 100 per cent R.H. at six different temperatures 15 ± 2°C, 20 ± 2°C, 25 ± 2°C, 30 ± 2°C, 35 ± 2°C and 40 ± 2°C, maintained in an incubator to study the effect of different levels of temperature and relative humidity upon the incubation period and percentage of hatching of eggs. Each observation was based on five replicates and each replicate containing 100 eggs. The results are included under the sub-heading of the observation "Effect of different levels of temperature and relative

humidity on the incubation period and hatching of eggs of Dysdercus cingulatus Fab."

(5) Five sets of experiments were performed to study the effect of five different host plants, i.e., Gossypium hirsutum, Abelmoschus esculentus, Althea rosea, Thespesia populnea and Abutilon indicum on nymphs and adults of D. cingulatus Fab. Each set of experiments contained 20 newly hatched first instar nymphs. These first instar nymphs were reared separately in glass tubes, each measuring 9 cm x 2 cm. (Fig.1-C), covered with muslin cloth and tied with rubber band, at 30 ± 2°C and 80 ± 5 per cent R.H., and fed on seeds of above host plants soaked in water. The observation on nymphal duration and body weight of nymphs and adults were recorded. The newly emerged adults were kept in pairs separately in glass jars, each measuring 15 cm x 10 cm., provided with 1.00 cm. thick sterilized moist sand layer at the bottom for oviposition and covered with muslin cloth and tied with rubber band. They were fed on above five different host plants, to study the fecundity, viability of eggs and longevity of adults at 30 ± 2 C and 80 ± 5 per cent R.H. The observation were recorded based on ten replicates for each host plant. The results are included under the sub-heading of the observation

"Influence of different host plants on the nymphs and adults of Dysdercus cingulatus Fab. under laboratory conditions."

(6) 28 pairs of newly emerged adults of Dysdercus cingulatus Fab. were obtained from the stock. Each pair was kept separately in glass jar, each measuring 20 cm x 15 cm., covered with muslin cloth and tied with rubber band. Each jar was provided with 1.0 cm. thick moist sterilized sand layer at the bottom for oviposition and kept at 30 ± 2°C and 80 ± 5 per cent R.H., maintained in an incubator and cotton balls soaked in water were provided as food on alternate days. The above experiment was also repeated with 28 pairs of newly emerged adults in each glass jar, each measuring 15 cm x 10 cm. in order to study the effect of crowding stress on the fecundity and viability of eggs of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. The eggs obtained from isolated and crowded conditions were kept separately at 30 ± 2°C and R.H. 80 ± 5 per cent in incubator for hatching. The observations on fecundity and viability of eggs under isolated and crowded conditions were recorded. The results are included under the sub-heading of the observation "Effect of crowding stress on the fecundity and viability of eggs of Dysdercus cingulatus Fab. under laboratory conditions".

(7) 35 pairs of newly emerged adults of Dysdercus cingulatus Fab., were obtained from the stock and reared in glass jar, measuring 20 cm x 15 cm., at 30 ± 2°C and 80 ± 5 per cent R.H., fed on cotton bolls soaked in water. Fresh food was given on alternate days. The glass jar was provided with 1.00 cm. thick moist sterilized sand layer at the bottom for oviposition. Out of these, five pairs were dissected daily for seven days, till the end of the first oviposition, to study the length of egg E_1 and egg E_2, maturation of gonads, variation in number of ovarioles per ovary, number of developing eggs per ovarioles. The observations on eggs, sexual maturation of gonads, variation in number of ovarioles per ovary and developing eggs per ovariole were recorded.

(8) Ten pairs of newly emerged adults of Dysdercus cingulatus Fab., were obtained from the stock and reared separately in glass jars, each measuring 15 cm x 10 cm., at 35 ± 2°C and 70 ± 5 per cent R.H., in an incubator and fed on cotton bolls soaked in water. Fresh food was provided on alternate days. The size and weight of newly emerged adults and mature adults were recorded. Fluctuation in body weight of ~~adults~~ male and female adults was also recorded till their death. The results of the experiments no. (7) and (8)

are included under the sub-heading of the observations "Biometric observations on the sexual maturation of gonads of Dysdercus cingulatus Fab. under laboratory conditions".

OBSERVATIONS

(A) Development of *Dysdercus cingulatus* Fab. at constant ecological conditions in the laboratory.

The following observations were made from the first set of experiments :-

(i) Adults :

Male: Body size moderate, length 12.6 mm. and width 4.2 mm. across the pronotum, generally bright reddish colour; head opisthognathous, length 1.6 mm. and width 1.8 mm; antennae filiform, 4-segmented, length 7.7 mm., terminal segment length 2.7 mm; proboscis 4-jointed, length 6.2 mm; thorax length 2.0 mm; abdomen length 9.0 mm; hind-femur length 4.2 mm; wings ochraceous; mouth parts piercing and suctorial type (Table 1).

Female :- Body size moderate, length 14.5 mm. and width 4.6 mm. across the pronotum, generally bright reddish colour; head opisthognathous, length 2.0 mm. and width 2.2 mm; antennae filiform, 4-segmented, length 8.9 mm., terminal segment length 3.0 mm; proboscis 4-jointed, length 6.7 mm; thorax length 2.5 mm; abdomen length 10.0 mm; hind-femur

length 4.4 mm; wings ocharceous; mouth parts piercing and suctorial type (Table 1).

(ii) Copulation :

Dysdercus cingulatus Fab. copulates freely under the laboratory conditions at 30 ± 2°C and 80 ± 5 per cent R.H. Sexual activity is more vigorous during the months of October to February at Aligarh. The male only initiates the courtship and remains docile where as females remain active during courtship. The male is small in size than the female. It rides over the larger female and brings the posterior part of its abdomen near the posterior part of the abdomen of the female. Then it protrudes and inserts its aedeagus into the vagina of the female and becomes locked immediately. The male then turns back and keep its head in opposite direction to each other (Fig. 3). The female being larger in size determines the direction of the movement during copulation. The copulation period varies from 55 to 120 hours in different females at different intervals. The pre-copulation period is 3.5 days. Copulation has also been observed with the dead females for 2 to 3 hours under the laboratory conditions at 30 ± 2°C and 80 ± 5 per cent R.H. (Fig. 4).

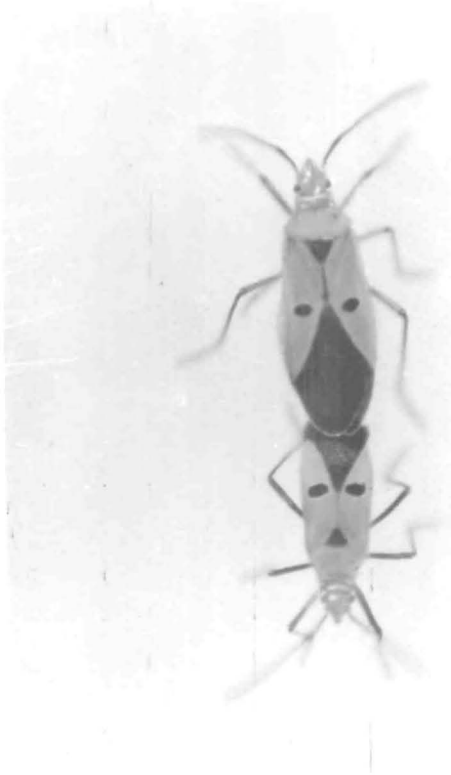

Figure 3. Dysdercus cingulatus Fab., copulating pair, showing the mode of copulation.

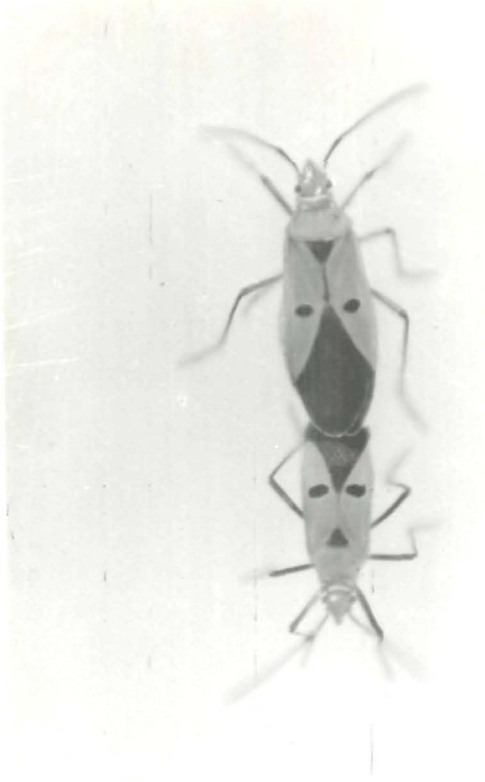

Figure 3. Dysdercus cingulatus Fab., copulating pair, showing the mode of copulation.

Figure 4. Dysdercus cingulatus Fab., male copulating with dead female.

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(iii) Pre-oviposition, oviposition and post-oviposition periods :

Pre-oviposition period is 6.0 days. The oviposition period is also 6.0 days at 30 ± 2°C and R.H. 80 ± 5 per cent. The females deposit their eggs in batches on the moist sterilized sand layers or in the cracks of the soft sand and covers the eggs with the cotton bolls in the glass jars. The post-oviposition period is 2.5 days at 30 ± 2°C and 80 ± 5 per cent R.H.

(iv) Egg :

Freshly laid egg is white in colour and oval shaped. Its length is 1.4 mm. and width is 0.95 mm. (Fig. 5). The size varies from egg to egg. During the incubation period the colour changes from white to yellow and finally becomes orange within a couple of days. The average number of eggs laid per female is 214.5 ± 0.353 at 30 ± 2°C and 80 ± 5 per cent R.H.

(v) Hatching :

The egg of Dysdercus cingulatus Fab. hatches in 5 to 6 days at 30 ± 2°C and 80 ± 5 per cent R.H., and the average incubation period is 5.5 days. The incubation period varies with the variation in temperature and relative humidity. At the time of hatching, the operculum ruptures and the young

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Figure 5. Eggs of Dysdercus cingulatus Fab.

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nymph inside the egg pushes the lid away and comes out on the surface of the moist sand layer in the glass jars. The average percentage of hatching is 96.0 ± 0.360 at 30 ± 2°C and 80 ± 5 per cent R.H.

(vi) Description of different nymphal instars :

The following observations were made from the second set of experiments :-

There are five nymphal instars in both the sexes of Dysdercus cingulatus Fab. (Table 1).

First nymphal instar : Oval shape; colour light yellow and becomes generally reddish within 24 hours, length 2.075 mm. and width 1.0 mm; head triangular, opisthognathous, length 0.55 mm. and width 0.55 and 0.57 mm. for male and female respectively; antennae filiform, 4-segmented, length 1.125 mm. terminal segment length 0.525 mm; proboscis 4-jointed, length 1.0 mm.; thorax length 0.5 mm; abdomen length 0.975 mm; hind femur length 0.5 mm. Two tarsi in each leg. It extends for 2-3 days.

Second nymphal instar : Colour deep reddish, length 2.325 mm. and width 1.075 mm; head triangular, opisthognathous, length

0.575 mm. and width 0.712 mm. and 0.775 mm for male and female respectively; antennae filiform, 4-segmented, length 2.15 mm, terminal segment length 0.875 mm; proboscis 4-jointed, length 2.175 mm; thorax length 0.5 mm; abdomen length 1.250 mm; hind-femur length 0.875 mm. It extends for 2-3 days.

Third nymphal instar : Generally deep reddish colour, length, 4.65 mm. and width 1.825 mm.; head triangular, opisthoganathous, length 1.075 mm; and width 1.0 mm. and 1.225 mm. for male and female respectively; antennae filiform, 4-segmented, length 3.25 mm; terminal segment length 1.175 mm.; proboscis 4-jointed length 2.025 mm; thorax length 1.025 mm; abdomen length 2.55 mm; hind-femur length 1.375mmm; mesothoracic wing-pads appear. It extends for 2-4 days.

Fourth nymphal instar: Generally deep reddish colour, length 6.2 mm. and width 2.425 mm; head triangular, opisthognathous , length 1.575 mm. and width 1.250 mm. and 1.4 mm. for male and female respectively; antennae filiform, 4-segmented, length 5.235 mm.; terminal segment length 1.75 mm; proboscis 4-jointed, length 4.875 mm; thorax length 1.75 mm; abdomen length 2.825 mm; hind femur length 2.657 mm; wing-pads black colour. It extends for 5-6 days.

Fifth nymphal instar : Generally deep reddish colour, length 9.7 mm. and width 3.6 mm; head triangular, opisthognathous, length 1.6 mm. and width 1.65 mm. and 1.85 mm for male and female respectively; antennae filiform, 4-segmented, length 7.6 mm., terminal segment length 2.5 mm; proboscis 4-jointed length 6.2 mm.; thorax length 1.8 mm; abdomen length 6.3 mm; hind-femur length 4.5 mm; presence of long black wing-pads. It extends for 6-8 days.

(vii) Application of Dyar's law : During the course of second set of experiments the author applied Dyar's law (1890) to the different nymphal instars of Dysdercus cingulatus Fab.

The head width in successive nymphal instars increases in a geometrical progression. The average ratio of increase in the width of the head capsule in each nymphal instar is 1.317 for male and 1.347 for female. Both the sexes have five nymphal instars. The calculated width is found close to the observed head width (Table 2, Fig. 6 a & b). Thus these figures serve to determine the number of instars and to eliminate the possibility of missing any ecdysis in the life cycle.

Although the above ratio is not completely identical and these are sufficiently close to indicate that the increase

TABLE 1

Measurement of different body parts of Dysdercus cingulatus Fab. reared at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

Body Parts	Nymphal instars					Adults	
	I (mm.)	II (mm.)	III (mm.)	IV (mm.)	V (mm.)	Male (mm)	Female (mm.)
Body length	2.025	2.325	4.65	6.2	9.7	12.6	14.5
Body width	1.000	1.075	1.825	2.425	3.6	4.2	4.6
Head Length	0.55	0.575	1.075	1.575	1.6	1.6	2.0
Antenna length	1.125	2.15	3.25	5.325	7.6	7.7	8.9
Terminal antennal segment	0.525	0.875	1.175	1.75	2.5	2.7	3.0
Proboscis length	1.0	2.175	2.925	4.875	6.0	6.2	6.7
Thorax length	0.50	0.50	1.025	1.75	1.8	2.0	2.5
Abdomen length	0.975	1.25	2.55	2.825	6.3	9.0	10.0
Hind femur length	0.50	0.875	1.375	2.675	4.5	4.2	4.4

TABLE 2

Observed and calculated width of the head capsules of different nymphal instars of *Dysdercus cingulatus* Fab. reared at 30 ± 2°C and 80 ± 5 per cent relative humidity and fed on cotton bolls soaked in water. (Each observation is based on ten replicates).

Sex	Nymphal instars	Observed width of the head capsule (mm.)	Calculated width of the head capsule of the nymphal instars (mm.) (observed width of the head capsule x average ratio of increase in width of the head capsules of the nymphal instars)
Male with five nymphal instars	First nymphal instar	0.550	-
	Second nymphal instar	0.712	0.550 x 1.317 = 0.724
	Third nymphal instar	1.000	0.712 x 1.317 = 0.937
	Fourth nymphal instar	1.250	1.000 x 1.317 = 1.317
	Fifth nymphal instar	1.650	1.250 x 1.317 = 1.646
Female with five nymphal instars	First nymphal instar	0.575	-
	Second nymphal instar	0.775	0.575 x 1.347 = 0.774
	Third nymphal instar	1.225	0.775 x 1.347 = 1.043
	Fourth nymphal instar	1.400	1.225 x 1.347 = 1.650
	Fifth nymphal instar	1.850	1.400 x 1.347 = 1.885

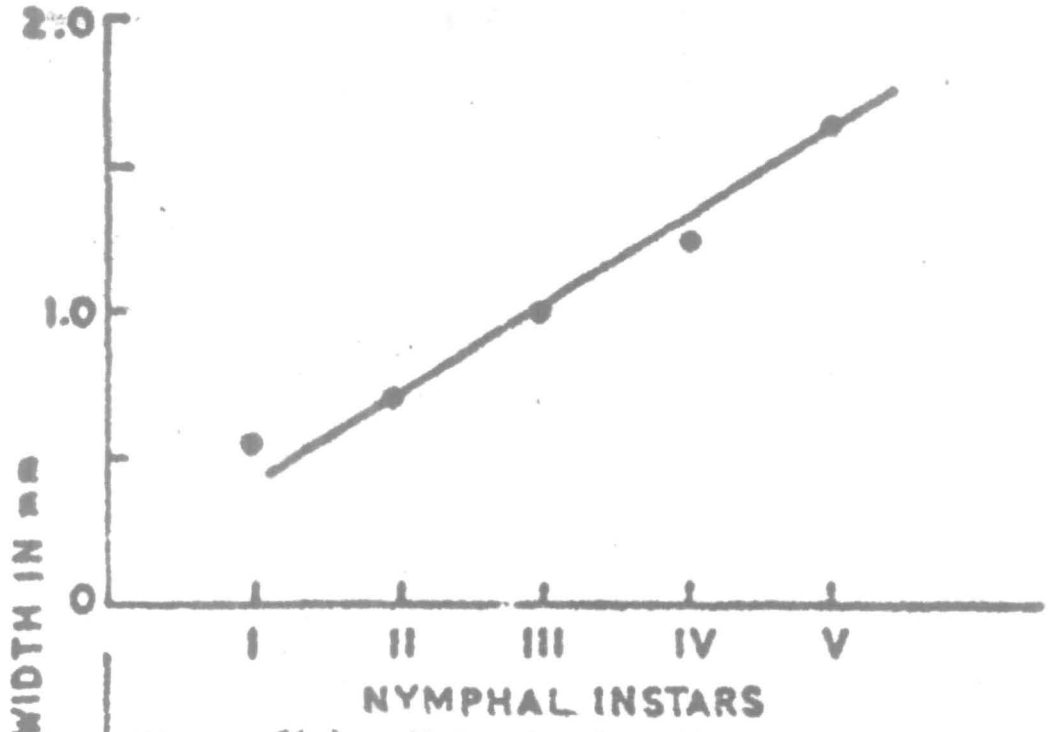

Figure 6(a). Males having five nymphal instars.

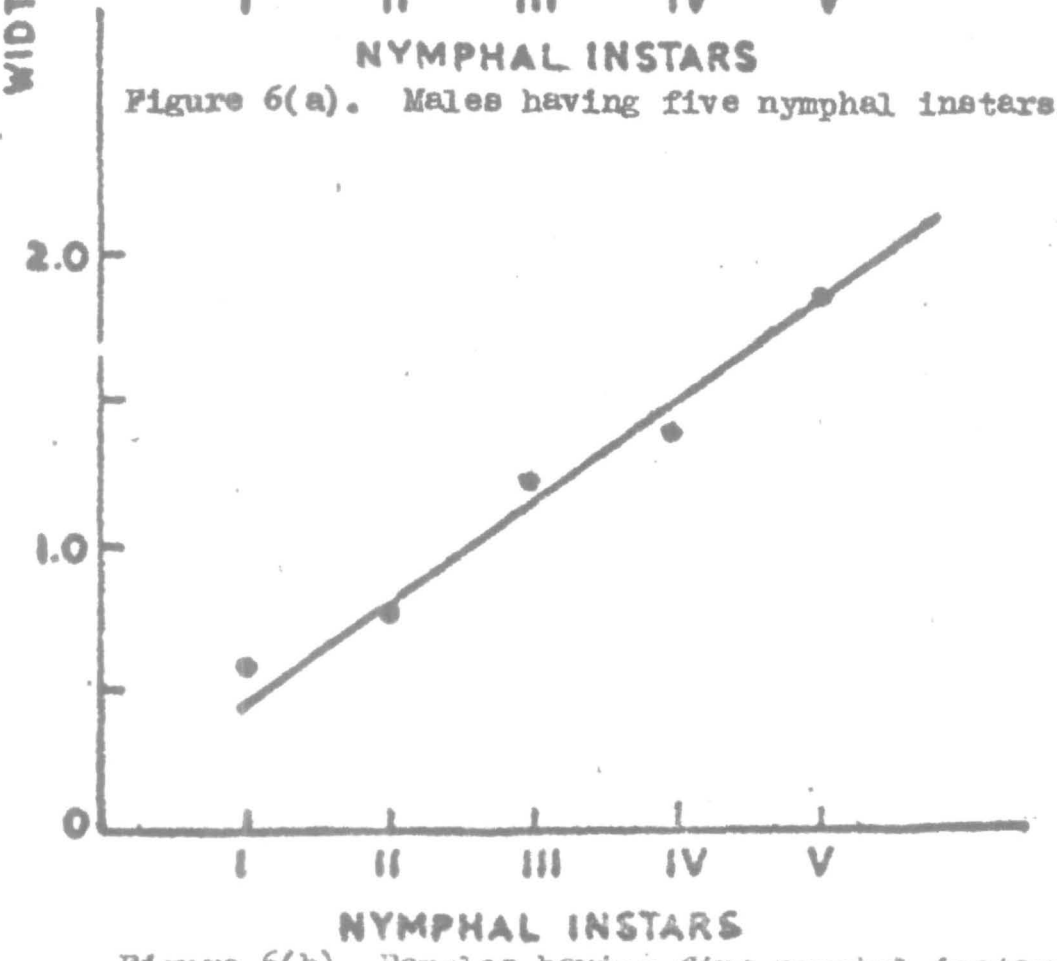

Figure 6(b). Females having five nymphal instars.

in the head width follows Dyar's law. The slight variation could be due to the small number of measurements which has been taken in each nymphal instar and also owing to sex differentiation.

(viii) Sex ratio : The following observations were made from the third set of experiments:-

The ratio of male Dysdercus cingulatus Fab. to female is 1.41 : 1, that is, the males are slightly more in number than the females (Table 3).

(ix) Survival of adults : The following observations were made from the third set of experiments :-

The average percentage of adults emerged from the nymphal instars is 55.25. This is the survival of adults of Dysdercus cingulatus Fab. emerged from nymphal instars and the mortality observed is 44.75 per cent, fed on cotton bolls soaked in water at 30 ± 2°C and 80 ± 5 per cent R.H. (Table 4).

TABLE 3

Sex ratio of *Dysdercus cingulatus* Fab. reared at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

No. of replicates	Male	Female	Sex ratio
1.	41	31	1.32 : 1
2.	35	35	1.0 : 1
3.	38	28	1.35 : 1
4.	24	15	1.6 : 1
5.	17	7	2.42 : 1
6.	37	27	1.37 : 1
7.	28	20	1.40 : 1
8.	12	9	1.33 : 1
9.	31	26	1.19 : 1
10.	24	20	1.2 : 1
		Average sex ratio	1.41 : 1

TABLE 4

Survival of adults of *Dysdercus cingulatus* Fab. reared at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

Eggs laid	Eggs hatched (nymphs)	Eggs unhatched	Adults emerged (survival)	Survival (per cent)
100	98	2	41	41.83
100	94	6	51	54.25
98	94	4	69	73.40
122	120	2	60	50.00
93	90	3	45	50.00
75	73	2	48	65.74
97	97	0	50	51.54

Average percentage of survival = 55.25

Average percentage of mortality = 44.75

(B) Effect of different levels of temperature and relative humidity on the incubation period and hatching of eggs of Dysdercus cingulatus Fab.

The following observations were made from the fourth set of experiments:-

It is evident from Table 5, Fig. 7, that temperature and relative humidity affect the incubation period and the hatching of eggs of Dysdercus cingulatus Fab. The incubation period is accelerated with the increase in temperature upto 35 ± 2°C. But at lower temperatures it is adversely affected. The incubation period is not affected by different levels of R.H. at 25 ± 2°C and 30 ± 2°C and it is favourably influenced by the temperature in the range of 25 ± 2°C to 30 ± 2°C at all the R.H. The hatching rate is influenced by R.H. and the percentage of hatching is low at lower humidities (Table 5).

The optimum temperature for the development of eggs is 30 ± 2°C with R.H. 80 ± 5 per cent. Irrespective of relative humidities, the eggs did not hatch at 15 ± 2°C and 40 ± 2°C. The minimum hatching of eggs is at 20 ± 2°C with respect to all the relative humidities. The adverse effect on the

hatching of eggs may be observed at 15 ± 2°C with all the R.H., 35 ± 2°C with 40 ± 5 and 60 ± 5 per cent R.H. and 40 ± 2°C with all the R.H. The maximum percentage of hatching of eggs is 96.0 ± 0.360 at 30 ± 2°C with R.H. 80 ± 5 per cent, while it is minimum (45.0 ± 0.338 per cent) at 20 ± 2°C with R.H. 40 ± 5 per cent (Table 5).

TABLE 5

Effect of different levels of temperature and relative humidity on the incubation period and hatching of eggs of *Dysdercus cingulatus* Fab. (Range of incubation period is given in parentheses).

Temperature °C	Relative humidity (R. H.)	Eggs hatched (per cent) ±S.E.	Incubation period (days)
15 ± 2	40 ± 5	-	-
	60 ± 5	-	-
	80 ± 5	-	-
	100	-	-
20 ± 2	40 ± 5	45.0 ± 0.338	17.5 (17-18)
	60 ± 5	70.0 ± 0.353	17.5 (17-18)
	80 ± 5	85.0 ± 0.398	17.5 (17-18)
	100	60.0 ± 0.330	17.5 (17-18)
25 ± 2	40 ± 5	47.0 ± 0.325	6.5 (6-7)
	60 ± 5	72.0 ± 0.325	6.5 (6-7)
	80 ± 5	85.0 ± 0.353	6.5 (6-7)
	100	61.0 ± 0.361	6.5 (6-7)
30 ± 2	40 ± 5	62.0 ± 0.354	5.5 (5-6)
	60 ± 5	75.0 ± 0.374	5.5 (5-6)
	80 ± 5	96.0 ± 0.360	5.5 (5-6)
	100	85.0 ± 0.353	5.5 (5-6)
35 ± 2	40 ± 5	-	-
	60 ± 5	-	-
	80 ± 5	81.0 ± 0.366	5
	100	64.0 ± 0.365	5
40 ± 2	40 ± 5	-	-
	60 ± 5	-	-
	80 ± 5	-	-
	100	-	-

S.E. = Standard error.

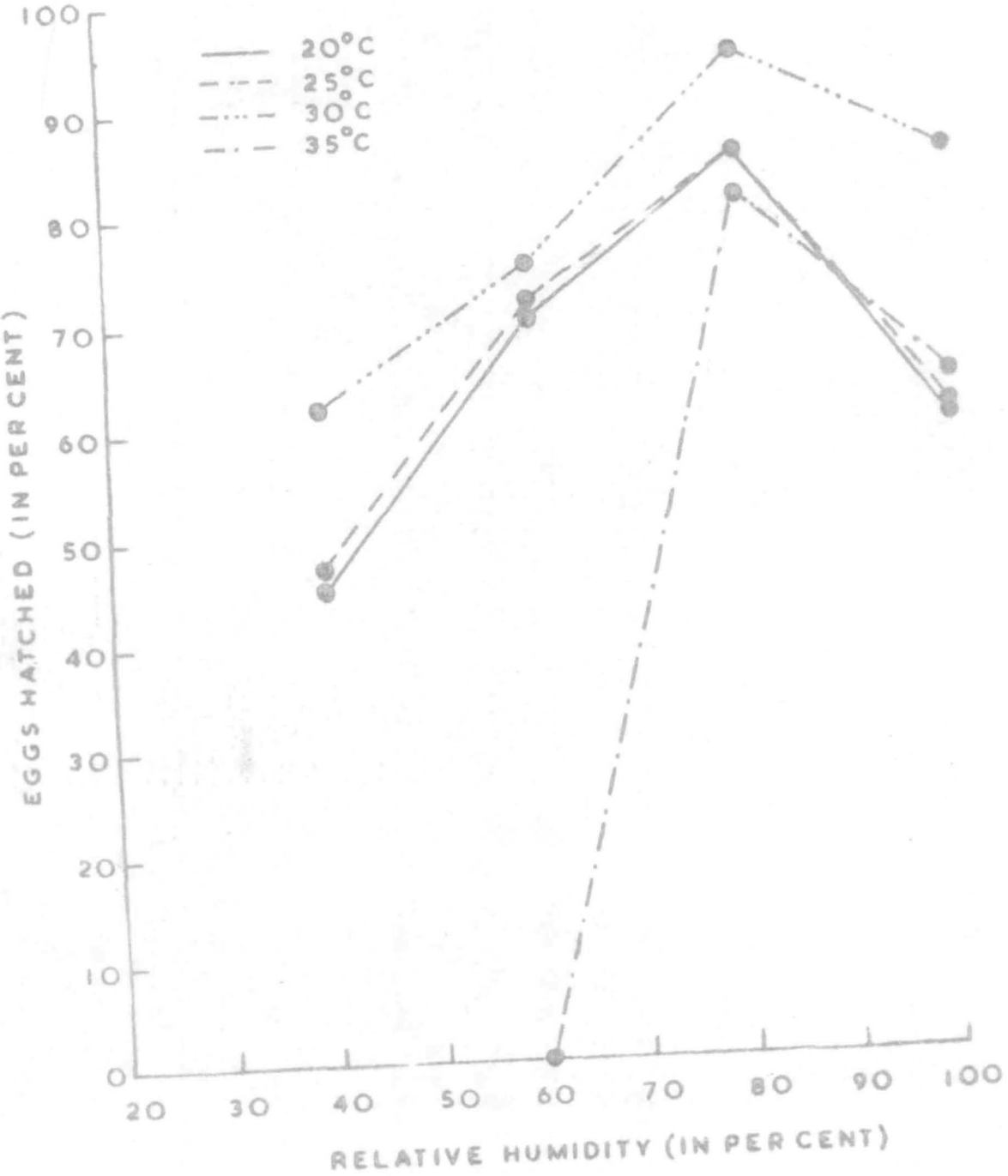

Figure 7. Effect of different levels of temperature and relative humidity on the hatching of eggs of Dysdercus cingulatus Fab.

(C) Influence of different host plants on nymphs and adults of Dysdercus cingulatus Fab. under laboratory conditions.

(i) Nymphal duration :

The following observations were made from fifth set of experiments :-

It is evident from the Table 6 that the development rate of nymphs is rapid when fed on Gossypium hirsutum (26.5 days), while it is slow on Thespesia populnea (32.5 days) at 30 ± 2°C and 80 ± 5 per cent R.H. On the basis of the development rate of nymphs, the host plants may be arranged in the following declining sequence : Gossypium hirsutum, Abelmoschus esculentus, Althea rosea, Abutilon indicum and Thespesia populnea.

(ii) Body weight of different nymphal instars and adults fed on different host plants :

The following observations were made from the fifth set of experiments :-

It is evident from the Table 7 that the newly emerged adults weigh more when fed on Gossypium hirsutum (29.04 mg.

TABLE 6

Effect of different host plants on the development of *Dysdercus cingulatus* Fab. reared at 30 ± 2°C and 80 ± 5 per cent R.H.

Name of Host plant	Incubation period of eggs (days)	Nymphal duration (days)					Total duration (days)
		I	II	III	IV	V	
Gossypium hirsutum	5.5 (5-6)	2.5 (2-3)	2.5 (2-3)	3.5 (3-4)	5.5 (5-6)	7.0 (6-8)	26.5 (23-30)
Abelmoschus esculentus	5.5 (5-6)	2.5 (2-3)	2.5 (2-3)	4.0 (3-5)	6.0 (5-7)	7.5 (6-9)	28.0 (23-33)
Althea rosea	5.5 (5-6)	3.0 (2-4)	3.0 (2-4)	4.0 (3-5)	6.0 (5-7)	8.0 (6-10)	29.5 (23-36)
Abutilon indicum	5.5 (5-6)	3.0 (2-4)	3.5 (3-4)	4.5 (3-6)	6.5 (5-8)	8.5 (6-11)	31.5 (24-39)
Thespesia populnea	5.5 (5-6)	3.0 (2-4)	3.5 (3-4)	4.5 (3-6)	7.0 (5-9)	9.0 (6-12)	32.5 (24-41)

Range is given in parentheses.

TABLE 7

Growth rate by weight of *Dysdercus cingulatus* Fab. during post embryonic development at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on different host plants.

Name of Host plant	Nymphal instars					Adults (N.E.) (mg.)
	I (mg.)	II (mg.)	III (mg.)	IV (mg.)	V (mg.)	
Gossypium hirsutum	0.5 (0.5)	1.0 (1.5)	4.5 (5.5)	13.0 (15.0)	20.0 (26.0)	29.04 (72.5)
Abelmoschus esculentus	0.5 (0.5)	0.9 (1.3)	4.3 (5.2)	12.5 (14.6)	19.0 (25.5)	28.2 (72.0)
Althea rosea	0.5 (0.5)	0.8 (1.1)	4.0 (5.0)	12.1 (14.1)	18.5 (25.1)	27.5 (71.4)
Abutilon indicum	0.45 (0.45)	0.7 (0.9)	3.9 (4.5)	11.8 (13.5)	17.4 (24.6)	27.0 (71.1)
Thespesia populnea	0.45 (0.45)	0.7 (0.9)	3.8 (4.4)	11.5 (13.0)	16.0 (24.0)	25.5 (69.8)

Weight of female given in parentheses

N.E. = Newly emerged.

and 72.5 mg. for male and female respectively), while on Thespesia populnea the newly emerged adults weigh less (25.5 mg and 69.5 mg. for male and female respectively).

It is evident from the same table that the body weight of different nymphal instars and newly emerged adults of Dysdercus cingulatus Fab. is not significantly affected by different host plants at 30 ± 2°C and 80 ± 5 per cent R.H.

(iii) Fecundity :

The following observations were made from fifth set of experiments :-

It is evident from the Table 8, Fig. 8 that the maximum fecundity is 214.5 eggs per female when Dysdercus cingulatus Fab. is fed Gossypium hirsutum, while it is minimum (147.72 eggs per female) when fed on Thespesia populnea. The fecundity on different host plants may be arranged in the following descending order: Gossypium hirsutum, Abelmoschus esculentus, Althea rosea, Abutilon indicum and Thespesia populnea. It may , therefore, be concluded that the different host plants affect the fecundity of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H.

(iv) Viability of eggs :

The following observations were made from fifth set of experiments:-

It is evident from the table 8, Fig. 8 that the maximum viability of eggs (96.06 per cent) is recorded when Dysdercus cingulatus Fab., is fed on Gossypium hirsutum, while it is minimum (90.62 per cent) when fed on Thespesia populnea. On the basis of the viability of eggs the host plants may be arranged in the following descending order : Gossypium hirsutum, Abelmoschus esculentus, Althea rosea, Abutilon indicum and Thespesia populnea. So the different host plants affect the viability of eggs of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H.

(v) Longevity of adults :

The following observations were made from fifth set of experiments :-

It is evident from the Table 8, Fig. 9 that the maximum longevity is recorded when Dysdercus cingulatus Fab is fed on Gossypium hirsutum, while it is minimum on Thespesia populnea. The maximum longevity is 36.5 days for males and 19.5 days for females when fed on Gossypium hirsutum, while it is minimum

Table 8

Fecundity, viability of eggs, longevity of adults of *Dysdercus cingulatus* Fab. fed on different host plants at 30 ± 2°C and 80 ± 5 per cent R.H.

Name of Host plant	No. of eggs laid per female (Fecundity)	No. of eggs hatched (viable eggs) (Per cent)	No. of eggs unhatched (Non-viable eggs) (Per cent)	Average longevity of adult (days)	
				Male	Female
Gossypium hirsutum	214.5	96.06	3.94	36.5	19.5
Abelmoschus esculentus	205.0	95.55	4.45	35.5	19.0
Althea rosea	200.4	94.76	5.24	34.0	17.5
Abutilon indicum	191.3	94.01	5.99	32.5	15.5
Thespesia populnea	147.7	90.62	9.38	25.0	10.5

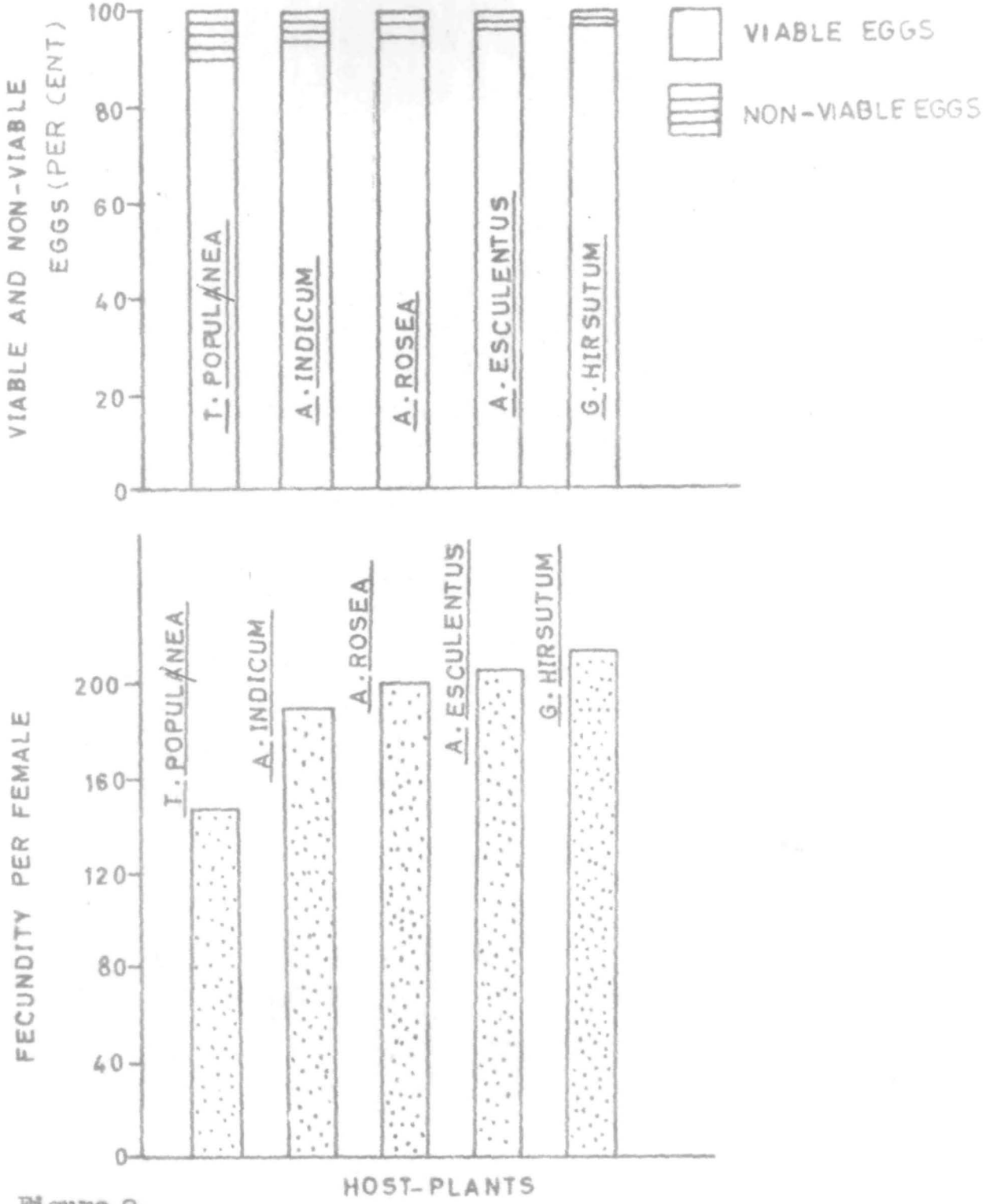

Figure 8. Effect of different host plants on the fecundity and viability of eggs of Dysdercus cingulatus Fab.

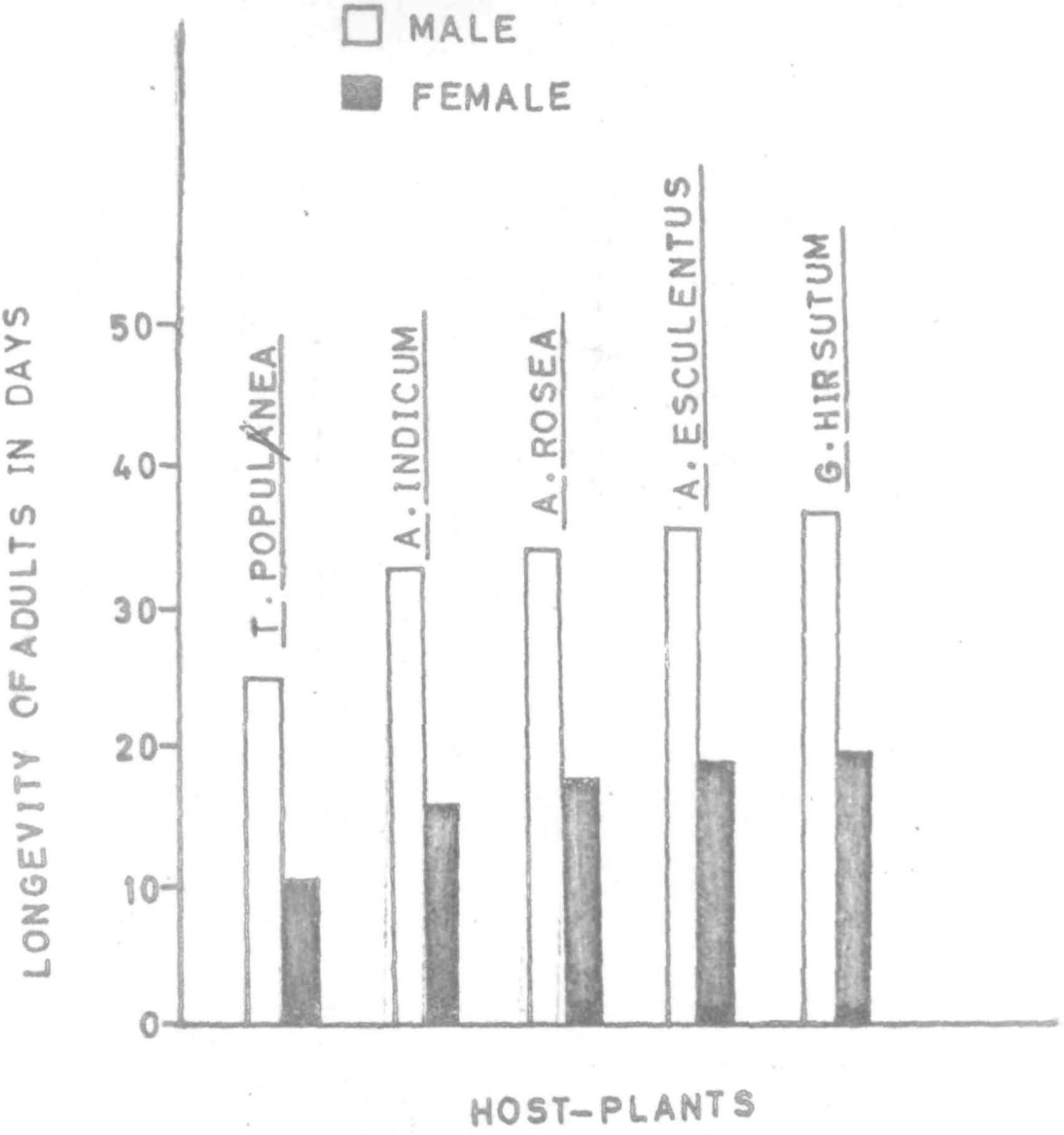

Figure 9. Effect of different host plants on the longevity of adults Dysdercus cingulatus Fab.

25.0 days and 10.5 days for males and females respectively when fed on Thespesia populnea at 30 ± 2°C and 80 ± 5 per cent R.H. On the basis of longevity of adult Dysdercus cingulatus Fab. the different host plants may be arranged in the following descending order: Gossypium hirsutum, Abelmoschus esculentus, Althea rosea, Abutilon indicum and Thespesia populnea. It may, therefore, be concluded that different host plants affect the longevity of adults of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H.

(D) Effect of crowding stress on the fecundity and viability of eggs of Dysdercus cingulatus Fab., under laboratory conditions.

The following observations were made from the sixth set of experiments :-

Crowding affects the fecundity and viability of eggs of Dysdercus cingulatus Fab., Six females died in the isolated as well as in the crowded condition. The remaining twenty two females laid 4720 eggs in isolated condition at an average of 214.5 ± 0.353 eggs per female, while in the crowded condition twenty two females laid 1340 eggs at an average of 60.9 ± 0.397 per female at 30 ± 2°C and 80 ± 5 per cent R.H. (Table 9, Fig. 10). The fecundity of adult female in isolated condition is much higher than the crowded ones. It may be concluded that the fecundity is adversely affected by the crowding stress. The viability of eggs is 96.06 ± 0.320 per cent in the isolated condition, while it is 82.16 ± 0.391 per cent in the crowded condition at 30 ± 2°C and 80 ± 5 per cent R.H. The percentage of non-viable eggs is higher (17.84 ± 0.360 per cent) in the crowded condition than in the isolated condition (3.94 ± 0.390) per cent (Table 10, Fig. 10). It is evident that the viability of eggs of Dysdercus cingulatus Fab. is adversely affected by the crowding stress.

TABLE 9

Effect of crowding stress on the fecundity of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent relative humidity and fed on cotton bolls soaked in water.

Rearing density	No. of females	No. of females died before oviposition	Total number of eggs laid	Average number of eggs laid per female (Fecundity) ± S.D.
ISOLATION (Space 20 cm x 15 cm)	28	6	4720	214.5 ± 0.353
CROWDED (Space 15 cm.x 10 cm)	28	6	1340	60.9± 0.397

S.E. = Standard error.

TABLE 10

Effect of crowding stress on the viability of eggs of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

Rearing density	No. of eggs kept for incubation	No. of eggs hatched (viable eggs)	No. of eggs unhatched (Non-viable eggs)	Percentage of viable eggs ± S.E.	Percentage of Non-viable eggs ± S.E.
ISOLATION (Space 20 cm x 15 cm.)	4720	4534	186	96.06 ± 0.320	3.94 ± 0.390
CROWDED (Space 15 cm. x 10 cm.)	1340	1101	239	82.16 ± 0.391	17.84 ± 0.360

S.E. = Standard error.

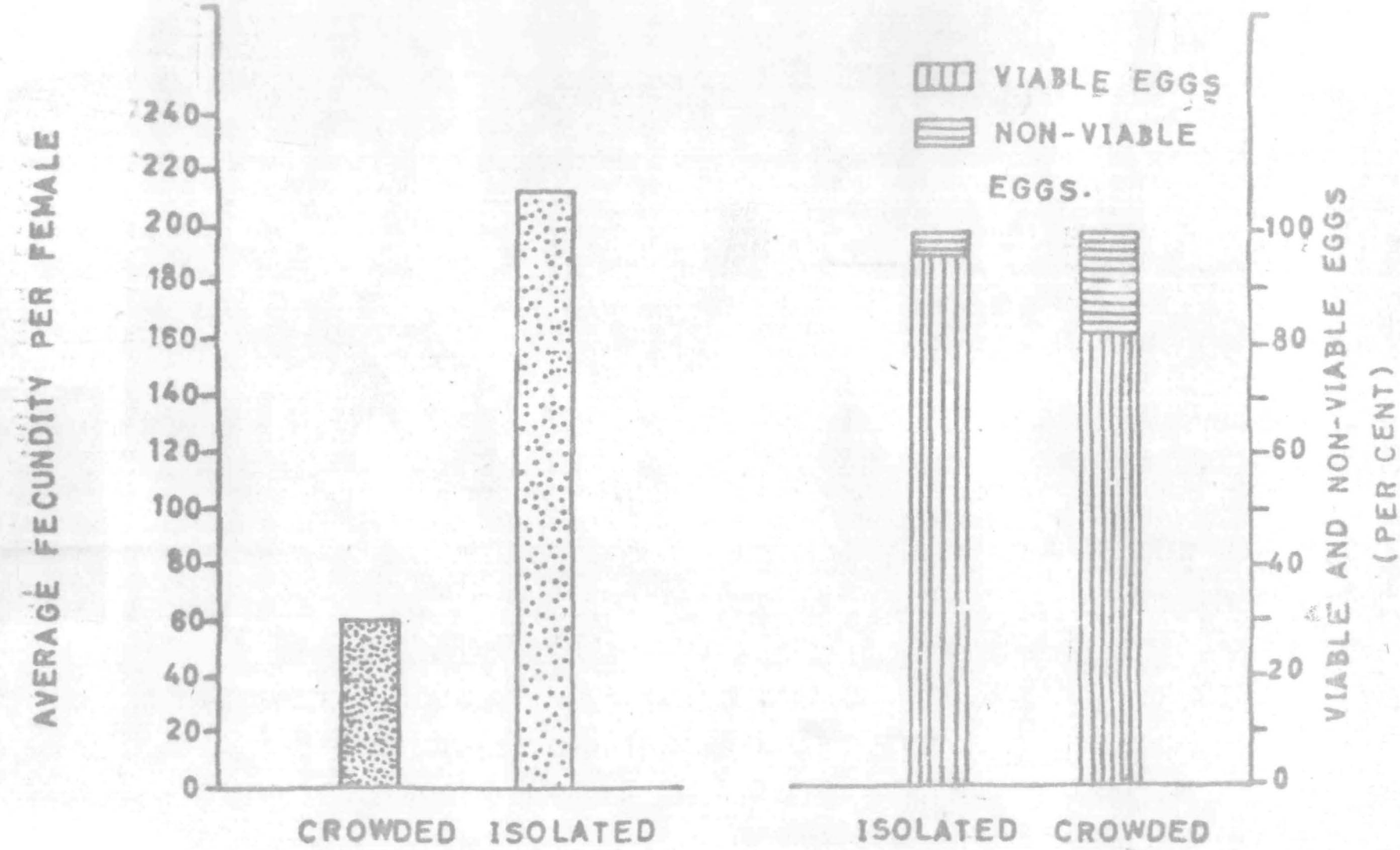

Figure 10. Effect of crowding stress on the fecundity and viability of eggs of Dysdercus cingulatus Fab.

(E) Biometric observations on the sexual maturation of gonads of Dysdercus cingulatus Fab., under laboratory conditions.

The following observations were made from the seventh set of experiments :-

(i) Gonads during sexual maturation :

Testes : The testes are small and immature just after the emergence of the male adults. During maturation these progressively increased in size and a yellow sheath developed around the testes and the seminal vesicles. A little increase in the length of the tubules of the accessory glands has been also observed. Considerable increase of fat in volume has been observed.

Ovaries : The ovaries of newly emerged female adults are small in size and white in colour. These increased considerably in size during the maturation and the ovarioles elongated and became quite prominent. The ovaries are of acrotrophic type consisting of a number of ovarioles, each of which contained a chain of developing eggs. The nutritive cells are found at the apex of the ovarioles. The egg nearest to

the oviduct is referred to as egg 1 (E_1), is largest in size and first to be ovulated. The eggs succeeding to it is referred to as egg 2 (E_2). Both E_1 and E_2 increase in size during the maturation. But when E_1 passes into the oviduct the rate of growth of E_2 is considerably accelerated. The linear regression of equation of length of egg 2 (Y) on length of egg 1 (x) has been observed as $(Y - 0.648) = 0.893\ (X - 0.818)$, where the coefficient of regression is 0.893. In order to test the significance of this regression coefficient, the Fisher-t is calculated :

$$t = \frac{(b - \beta)\ (n - 2)\ (\Sigma Xi^2 - n\bar{X}^2)}{(\Sigma Yi^2 - n\bar{Y}^2) + b^2\ (\Sigma Xi^2 - n\bar{X}^2) - 2b\ (\Sigma Xi\ Yi - n\bar{X}\ \bar{Y})}$$

where β is the population regression coefficient. In order to ascertain the linear regression in the population $b = 0$ against $b \neq 0$ is tested at 0.001 level of significance. The calculated value of 't' is less than the table value. Thus it should be accepted as null hypothesis, $b = 0$, i.e., significant otherwise rejected $b \neq 0$ (Table 11).

All E_1 eggs from the developed ovarioles of the ovary are deposited on the moist sand in the glass jars in

TABLE 11

Relative growth of egg 1 (X) and egg 2 (Y) in the adult female of Dysdercus cingulatus Fab. from their emergence upto the end of first oviposition and fed on cotton bolls soaked in water at 30 ± 2°C and 80 ± 5 per cent R.H. (Five females were dissected daily in each experiment).

Age (Days)	Average length (mm.)	
	Egg 1 (X)	Egg 2 (Y)
1.(N.E.)	0.5	0.45
2.	0.65	0.5
3.	0.746	0.54
4.	0.845	0.54
5.	0.925	0.65
6.	0.965	0.858
7.	1.1	1.0

N.E. = Newly emerged

quick succession followed by E_2 eggs in the second phase of oviposition. After ovulation, a yellowish ring of corpus luteum is left at the junction of ovariole and oviduct, which indicates that ovulation has taken place. Young females can be distinguished from the mature ones by thread like undeveloped ovarioles and the absence of corpora lutea and on the other hand, the old females can be identified by their empty ovarioles, distended oviducts and yellowish corpora lutea.

The number of ovarioles in an ovary varies from individual to individual and even in the right and left ovaries of the same individual. The number of ovarioles in the right and left ovaries in female adults varies from 5-7 (Table 12). The average number of developing eggs per ovariole varies from 8-12 and number of non-developing eggs per ovarioles varies from 1-2.

(ii) Weight and maturity:

The following observations were made from the eighth set of experiments :-

The average weight increase in male is 23.27 per cent, while in female it is 13.93 per cent. This steady increase in

TABLE 12

Variation in the number of ovarioles of the adult female of Dysdercus cingulatus Fab. (Five females were dissected daily) reared at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water

Age (Days)	Number of ovarioles in right and left ovary		
1. (N.E.)	5 + 5 (1)	5 + 6 (2)	7 + 5 (2)
2.	6 + 5 (2)	5 + 7 (2)	7 + 7 (1)
3.	7 + 7 (3)	6 + 7 (2)	
4.	7 + 6 (2)	7 + 5 (1)	7 + 7 (2)
5.	7 + 7 (5)		
6.	7 + 6 (3)	7 + 7 (2)	
7.	7 + 7 (3)	7 + 5 (2)	

Figures in parentheses indicate the number of females.

N.E. = Newly emerged.

weight occurs due to increase in egg size and due to development of fat bodies and accessory glands. The average increase in length of the male is 8.33 per cent, while in female it is 7.14 per cent during maturation (Table 13).

The weight of adult females after maturation fluctuates from day to day and after each oviposition (Fig. 11). The increase in weight is rapid in the beginning of a single female (Fig. 11).

The weight of an individual female is 133.6 mg. at the time of first oviposition and remains more or less constant at successive oviposition and falls just before the death. Similarly the weight of a single male fluctuates from day to day and it is less as compared with a single female. There is no sudden fall in weight of a single male just before its death as in the case of a single female.

TABLE 13

Weight and length of adult of *Dysdercus cingulatus* Fab. reared at 35 ± 2°C and 70 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

Sex	Average weight			Average length		
	Newly emerged adult (mg.)	Mature adult (mg.)	Increase in weight (Per cent)	Newly emerged adult (cm.)	Mature adult (cm.)	Increase in length (Per cent)
Male	29.04	35.8	23.27	1.2	1.3	8.33
Female	72.5	82.6	13.93	1.4	1.5	7.14

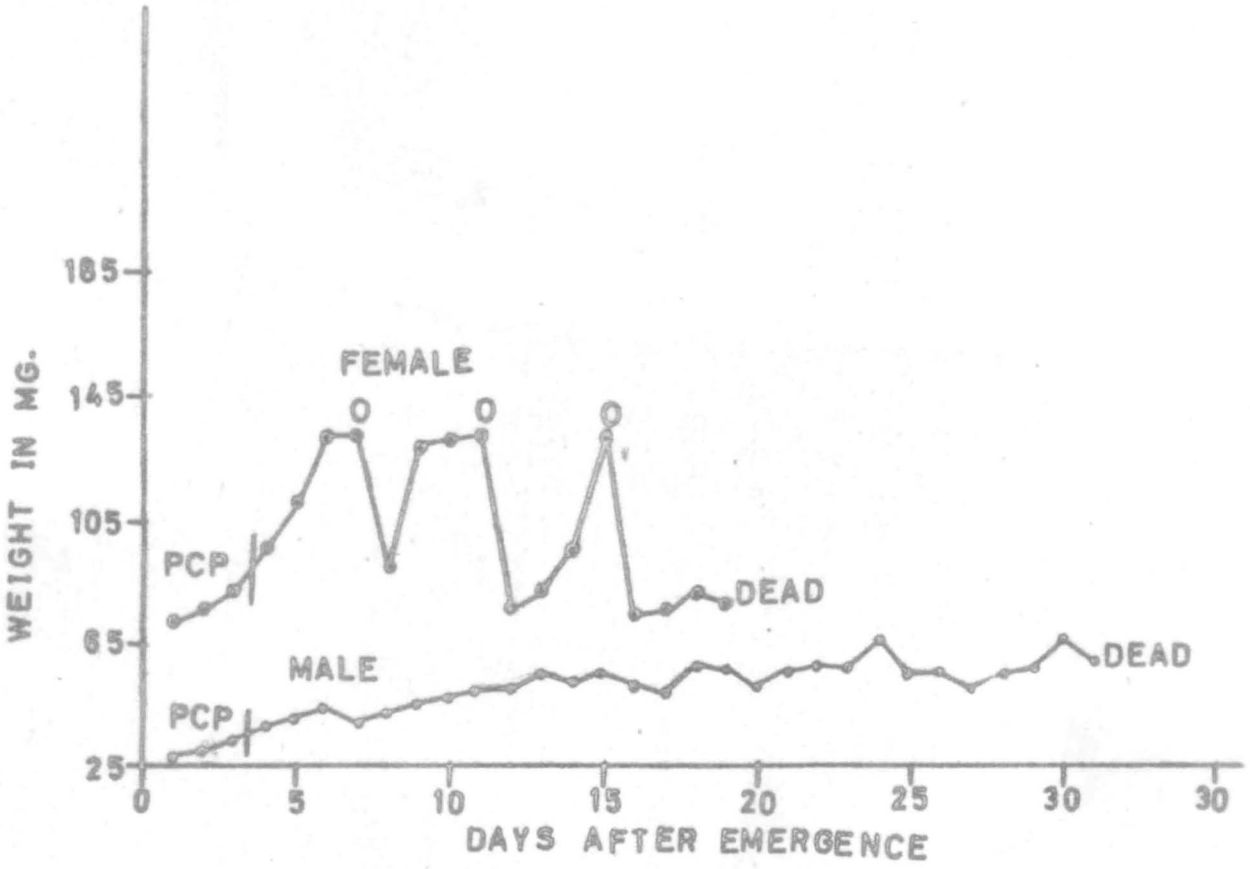

Figure 11. Fluctuations in the body weight of adults Dysdercus cingulatus Fab.

DISCUSSION

The cotton stainer, Dysdercus cingulatus Fab. is commonly known as red cotton bug. It is a polyphagous pest, especially a serious and major pest of cotton (Gossypium spp.) throughout India. Besides cotton, it is also found at Aligarh actively feeding and copulating an several other Malvaceous plants, i.e., Abelmoschus esculentus, Althea rosea, Sida acuta, Thespesia populnea and Abutilon indicum, etc., during the months of october to February, as alternative to host plant Gossypium hirsutum. They also attack a number of plants belonging to the families : Graminae, Cruciferae, and Cucurbitaceae. Similar observations have also been recorded by Sohi (1964). It also causes much damage to Hibiscus, sugarcane and other plants in the absence of cotton plant (Gossypium spp.) in the field which is recorded in "Results of Cotton cultivation experiments" in Formosa (1936). Cotes (1893) reported that Dysdercus cingulatus feeds on Lagenaria vulgaris in Kanpur, and on Brassica oleracea in Calcutta. Singh (1972) observed adults of Dysdercus cingulatus Fab. feeding and copulating on Thespesia populnea (L.) tree. It is also reported that D. koenigii feeds on green pods of H. esculentus (Chatterjee

and Raychoudhri, 1960). Watson (1916) reported that D. delaunayi infests the food plants-Eriodendron anfructuosum and Thespesia populnea.

Dysdercus cingulatus Fab. copulates freely at 30±2°C and 80 ± 5 per cent R.H. under the laboratory conditions. The copulation period varies from 55 - 120 hours in different females at different intervals, while Srivastava and Bahadur (1958) recorded it to vary from 60 to 100 hours at 98-110°F during the summer months of April to June. It varies from 3 to 6 days at 65 - 70°F (Mehta, 1930), in D. cingulatus. Fab. It has been observed that male of D. cingulatus Fab. copulates with dead females for 2 to 3 hours under the laboratory conditions. Bhatia and Kaul made similar observations in Locusta and in one case it lasted for 22 hours.

The pre-copulation period is recorded 3.5 days in Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. Mehta (1930) has observed tit to vary from 3 to 9 days between 86° F to 98° F in Dysdercus cingulatus Fab. and it is extended upto 15 days in the range of 77°F to 87°F and 35 to 36 days at 69°F to 82°F.

The pre-oviposition period lasts for 6.0 days in Dysdercus cingulatus at 30 ± 2°C and 80 ± 5 per cent R.H.

The oviposition period also lasts for 6.0 days in Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. It varies from 7 to 16 days in D. nigrofasciatus (Ullyett, 1930). Mehta (1930) recorded it to vary from 3 to 6 days at 95°F and 13 to 20 days at 70°F to 86°F in Dysdercus cingulatus Fab. Bhatia and Kaul (1966) in D. koenigii recorded the oviposition period to be 22.2, 10.2 and 10.4 days at 20°C, 25°C and 30°C respectively. They also observed inter-oviposition period at 20°C, 25°C and 30°C to be 8.0, 4.6 and 3.8 days respectively. The post oviposition period is 2.5 days at 30 ± 2°C and 80 ± 5 per cent R.H.

Dysdercus cingulatus Fab. deposits its eggs on the moist sand or in the cracks of soft soil. Similar observations have been recorded by Mehta (1930) in the same species. D. Sidae (Ballard and Evans, 1928) deposits its eggs in one inch deep soil below the surface or under the substratum, while D. nigrofasciatus deposits its eggs near the base of the surrounding plants or in exposed cotton bolls (Hargreave and Taylor, 1937). Thangavelu (1978) recorded that adult D. laetus Kirby deposited its eggs in young and non-dehisced capsules of the host plant. Srivastava and Bahadur (1958) observed that females of D. cingulatus Fab. deposited their eggs into the soft soil by inserting the abdomen.

Oviposition in Dysdercus cingulatus Fab. is affected by different levels of temperature and relative humidity. The average number of eggs laid per female is 214.5 ± 0.353. at 30 ± 2°C and 80 ± 5 per cent R.H. The eggs are not laid below 20°C and above 35°C. Bhatia and Kaul (1966) have recorded that the eggs laid at 15°C in D. koenigii are less in number than the eggs laid at higher temperatures. Mehta (1930) in D. cingulatus Fab., Clarke and Sardesai (1959) in D. fasciatus Sign. and MacGill (1935) in D. howardii Ballou., reported that the oviposition is affected by temperature and relative humidity.

The average percentage of hatching of eggs is 96.0 ± 0.360 in Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. The incubation period is 5.5 days.

There are five nymphal instars in both the sexes of Dysdercus cingulatus Fab. and there is no variation in number of nymphal instars. Similar observations have been made by Srivastava and Bahadur (1958) in the same species.

Dyar's law (1890), has been successfully applied in different nymphal instars of Dysdercus cingulatus Fab.

The sex ratio of male Dysdercus cingulatus Fab. to female is 1.41 : 1. The males are slightly more in number

than the females. MacGill (1935) recorded this ratio to be 1.27 : 1 in D. howardi Ballou.

The average percentage of adults emerged from the nymphal instars is 55.25 in Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. Mac Gill (1935) observed in D. howardi Ballou., the maximum percentage of emergence is 65.7 and minimum percentage of emergence is 7.5.

The percentage of hatching of eggs of Dysdercus cingulatus. Fab. is affected by different levels of temperature and relative humidity. The percentage of hatching is maximum (96.0 ± 0.360 per cent) at 30 ± 2°C and 80 ± 5 per cent R.H., and it is minimum (45.0 ± 0.338 per cent) at 20 ± 2°C and 80 ± 5 per cent R.H. 100 per cent hatching has been observed by Vrydagh (1941) in D. superstitiosus at 30°C and 95.0 per cent R.H. and the incubation period decreased from 4.05 to 4 days. The incubation period is favourably influenced by the temperature in the range of 25 ± 2°C to 30 ± 2°C at all the R.H. and is adversely affected at lower temperatures at all the R.H. in D. cingulatus Fab. Mehta (1930) recorded maximum hatching at 94.1°F and R.H. 79 to 82 per cent and 5 to 7 days as incubation period. The eggs failed to hatch below 35°C in D. fasciatus Sign. (Clarke and Sardesai, 1959). Mac Gill (1945) recorded the optimum temperature and relative humidity to be 27°C and R.H. 75 per cent. for the development of eggs of D. howardi Ballou.

The development rate of Dysdercus cingulatus Fab. is fastest on Gossypium hirsutum (26.5 days) while it is slowest (32.5 days) on Thespesia populnea. Thangavelu (1978) recorded that the development rate of D. laetus was fastest on Abutilon indicum (31 days) and slowest on Hibiscus esculentus (39 days) and on other host plants it ranged in between. Geering and Coaker (1960) recorded greater nymphal duration of D. supersitiosus when reared on Sorghum grain as compared with cotton seeds (Gossypium spp.).

The weight of newly emerged adults of Dysdercus cingulatus Fab. is more (29.04 mg. and 72.5 mg. for male and female respectively) when reared on Gossypium hirsutum and weight is less (25.5 mg. and 69.8 mg. for male and female respectively) when reared on Thespesia populnea at 30 ± 2°C and 80 ± 5 per cent R.H. Thangavelu (1978) observed that freshly emerged adult male and female of D. laetus weighed 2.4 mg. and 2.7 mg. when reared on A. indicum. He also found the weight of male and female is 1.7 mg. and 2.0 mg respectively when reared on Hibiscus esculentus.

The fecundity of adult Dysdercus cingulatus Fab. is more (214.5 eggs per female) on Gossypium hirsutum and less (147.7 eggs per female) on Thespesia populnea at 30 ± 2°C

and 80 ± 5 per cent R.H. The viability of eggs is also more (96.06 per cent) on Gossypium hirsutum and less (90.62 per cent) on Thespesia populnea.

The longevity of male and female adults of Dysdercus cingulatus Fab. is 36.5 days and 19.5 days respectively when reared on Gossypium hirsutum and 25.0 days and 10.5 days respectively on Thespesia populnea at 30 ± 2°C and 80 ± 5 per cent R.H. Barbosa (1950) recorded the longevity of male and female adults of D. microfasciatus to be 48.8 days and 37.7 days respectively at 25°C and 100 per cent R.H. Mehta (1930) observed the longevity to vary from 75 to 93 days in male and female adults of Dysdercus cingulatus Fab. in the range of 55°F to 79°F and R.H. 65 per cent and these bugs died within few days at temperatures above 100°F even when the R.H. 40 to 80 per cent was favourable. The lethal temperature is 106°F at which the adults died within a few hours (Mehta, 1930).

Crowding stress affects the fecundity and viability of eggs of Dysdercus cingulatus Fab. The average fecundity of adult female in isolated condition is much higher (214.5± 0.353) than the crowded ones (60.9 ± 0.397). Similar observations have been made by Majeed and Aziz (1977) in Gastrimargus transversus Thumb. The viability of eggs of

Dysdercus cingulatus Fab. is higher (96.06 ± 0.320 per cent) in the isolated condition than the crowded ones (82.16 ± 0.391 per cent). Majeed and Aziz (1977) recorded highest viability of eggs of G. transversus Thunb. in the crowded condition than the isolated condition.

During the sexual maturation of Dysdercus cingulatus Fab., it has been observed that gonads increase in size due to the development of fat bodies, accessory glands and the eggs. The number of ovarioles varies in different adult females and even in the right and left ovaries of the same individual. The weight of adult males and females also increases alongwith the maturation, later on it fluctuates after each oviposition. Fluctuation of weight is much in females than the males. The linear regression of length egg 2 (Y) on egg 1 (X) is significant where $b = 0$ and not $b \neq 0$.

SUMMARY

The red cotton bug, *Dysdercus cingulatus* Fab. is a polyphagous pest, especially a major pest of cotton crop (*Gossypium* spp.) in India. Besides cotton, it is also found at Aligarh copulating and actively feeding on several other Malvaceous plants, i.e., *Althea rosea*, *Abelmoschus esculentus* *Sida acuta*, *Thespesia populnea* and *Abutilon indicum* during the months of October to February as alternative to host plant *Gossypium hirsutum*.

Dysdercus cingulatus Fab. were collected from and around the University Campus and reared in the laboratory at 30 ± 2°C and 80 ± 5 per cent relative humidity. Cotton bolls (*Gossypium hirsutum*) soaked in water were supplied as food on alternate days.

The male and female mature more or less at the same time. The pre-copulation period is 3.5 days. The copulation period varies from 55 to 120 hours. Copulation has also been observed with dead females for 2-3 hours. The pre-oviposition period is 6.0 days. The female deposits the eggs on the sterilized moist sand in the glass jars and covers it with cotton bolls. The oviposition period is also

6.0 days. The post-oviposition period is 2.5 days.

Freshly laid eggs are white in colour and oval in shape. It measures 1.4 mm. in length and 0.95 mm. in width. The average number of eggs laid per female is 214.5 ± 0.353 at 30 ± 2°C and 80 ± 5 per cent R.H. The average incubation period is 5.5 days and the average percentage of hatching of eggs is 96.0 ± 0.360 at 30 ± 2°C and 80 ± 5 per cent R.H.

There are five nymphal instars in both the sexes. The nymphal duration is 2.5 days, 2.5 days, 3.5 days, 5.5 days and 7.0 days for the first, second, third, fourth and fifth nymphal instars respectively at 30 ± 2°C and 80 ± 5 per cent R.H. The total developmental period including incubation period is 26.5 days for both the males and females of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. and fed on cotton bolls soaked in water.

Dyar's law has also been successfully applied to different nymphal instars of Dysdercus cingulatus Fab. No obligatory diapause occurs in any stage.

The sex ratio of male Dysdercus cingulatus Fab. to female is 1.41 : 1. Males are slightly more in number than the females.

The average percentage of adults emerged (survival) from the nymphal instars of Dysdercus cingulatus Fab. is 55.25 when fed on cotton bolls soaked in water at 30 ± 2°C and 80 ± 5 per cent R.H.

The different levels of temperature and relative humidity affect the incubation period and percentage of hatching of eggs of Dysdercus cingulatus Fab. The incubation period is favourably influenced by the temperature in the range of 25 ± 2°C to 30 ± 2°C at all the R.H. The optimum temperature for the development of eggs is 30 ± 2°C and R.H. 80 ± 5 per cent (with maximum percentage of hatching 96.0 ± 0.360), while it is minimum (45.0 ± 0.338 per cent) at 20 ± 2°C and 80 ± 5 per cent R.H.

It has been observed that different host plants affect the development of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. The development rate is fastest on Gossypium hirsutum (26.5 days) and slowest on Thespesia populnea (32.5 days).

The fecundity is maximum (214.5 eggs per female) when fed on Gossypium hirsutum than on Thespesia populnea (147.7 eggs per female) and viability of eggs is more (96.06 per cent) on Gossypium hirsutum than on Thespesia populnea (90.62 per cent).

The longevity of male and female adults of Dysdercus cingulatus Fab. is 36.5 days and 19.5 days respectively on Gossypium hirsutum, while it is 25.0 days and 10.5 days respectively on Thespesia populnea at 30 ± 2°C and 80 ± 5 per cent R.H.

The crowding stress affects the fecundity and viability of eggs of Dysdercus cingulatus Fab. at 30 ± 2°C and 80 ± 5 per cent R.H. The average fecundity of adult female in the isolated condition is much higher (214.5 ± 0.353) than the crowded ones (60.9 ± 0.397) and the viability of eggs in the isolated condition is also higher (96.06 ± 0.320 per cent) than the crowded ones(82.16 ± 0.391 per cent) when fed on cotton bolls soaked in water.

During the sexual maturation of gonads of Dysdercus cingulatus Fab., it has been observed that the gonads increase in size due to the development of fat bodies, accessory glands and the eggs. The number of ovarioles varies in different adult females and even in the right and left ovaries of an individual. The weight also increasesalong with the maturation, later on it fluctuates after each oviposition. Fluctuations of weight is more in females as compared with the males. The linear regression of length eggs 2 (Y) on egg 1 (X) is significant.

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REFERENCES

Ballard, E. and Evans, M.G., 1928: Bionomics of Dysdercus sidae Montr. in Queensland. Bull. Ent. Res. 18(3): 405 - 432.

Barbosa, A.J.S., 1950: A comparative study of bionomics of cotton stainers in Mozambique and measures for their control. Portug. Acta. biol: 1 - 24.

Bhatia, D.R., 1959: Copulation of locusts with dead females. Indian. J. Ent. 21(3): 220.

Bhatia, S.K. and Kaul, H.N., 1966: Effect of temperature on the development and oviposition of the red cotton bug, Dysdercus koenigii (Fab.) (Hemiptera:Pyrrhocoridae) and application of Pradhan's equation relating temperature to the development. Indian. J. Ent. 28(1): 45 - 54.

Chatterjee, N.B. and Raychoudhri, D.N., 1960: Bionomics of Dysdercus koenigii (Fabr.). Indian Agriculturist 4: 104 - 112.

Clarke, K.U. and Sardesai, J.B., 1959: An analysis of the effect of temperature upon the growth and reproduction of Dysdercus fasciatus Sign. I. The intrinsic rate of increase. Bull. ent. Res. 50(2): 387-405.

Cotes, E.C., 1893: "A conspectus of insects which affect crops in India". Indian. Mus. Notes 2(6): 75 - 76.

Dyar, H.G., 1890: The number of moults of Lepidopterus larvae. Psyche. 5: 420- 422.

Geering, Q.A. and Coaker, T.H., 1960: The effect of different plant foods on the fecundity, fertility and development of cotton stainers, Dysdercus superstitiosus Fab. Bull. ent. Res. 51(1): 61 - 76.

Hargreave, H. and Taylor, T.H.C., 1937: Reports on the investigations of cotton stainers (Dysdercus) for 1936. Rep. Dep. Agric. Uganda: 9 - 32.

Mac Gill, E.I., 1935: On the biology of Dysdercus howardi Ballou. Bull. ent. Res. 26: 155 - 162.

Mac Gill, E.I., 1945: On the biology of Dysdercus howardi Ballou. III. The effect of temperature and humidity on the life cycle. Bull. ent. Res. 35(4): 301-308.

Majeed, Q. and Aziz, S.A., 1977: Effect of crowding on the fecundity and viability of eggs of Gastrimargus transversus Thunb. (Orthoptera:Acrididae). J. ent. Res. 1(1): 55 - 57.

Mehta, D.R., 1930: Observations on the influence of temperature and humidity on the bionomics of Dysdercus cingulatus Fab. Bull. ent. Res. 21 (4): 547 - 562.

Narayanan, E.S. 1962: Insect pests of cotton in India. Indian central cotton committee Publication. pp. 1-14.

Pomeroy, A.W.J. and Golding, F.D., 1923: Observations on the life histories of the cotton stainer bugs of the genus Dysdercus and on their economic importance in the Southern province of Nigeria. 2nd. Ann. Bull. Nigeria. Agric. Dept: 23 - 58.

Pruthi, H.S., 1923: On the anatomy and bionomics of the red cotton bug Dysdercus cingulatus Fab. J. Proc. Agc. Soc. Bengal. 19: 15-42.

"Results of cotton cultivation experiments in Formosa 1936." Bull. res. Inst. Formosa: 122 (113).

Sohi, G.S., 1964: Pests of cotton. Entomology of India. Silver Jubiee Number of Indian J. Ent.. pp. 111-148

Srivastava, U.S. and Bahadur, J., 1958: Observations on the life history of the red cotton bug, Dysdercus cingulatus Fab. (Hemiptera: Pyrrhocoridae). Indian J. Ent. 20(3): 228 - 234.

Srivastava, R.P. and Gupta, R.S., 1971: Dysdercus cingulatus Fab. a new pest of wheat - a possible case of host cross over. Indian J. Ent. 33(3): 354.

Thangavelu, K., 1978: Some aspects of host specificity in the Indian dusky cotton bug, Oxycarenus laetus Kirby. (Hemiptera:Lygaeidae). J. nat. Hist. 12: 481-486.

Ullyett, G.C., 1930: The life histories, bionomics and control of cotton stainers (Dysdercus spp.) in South Africa. Bull. Dept. Agric. Un. S. Africa, 94: 1-9.

Vrydagh, J.M., 1941: Estude Sur La Bidogie Dysdercus superstitiosus. Publ. Inst. Estude. agron. cong. sci. 24 (19).

Watson, F., 1916: Work connected with insect and fungus pests and their control. Report. Agric. Dept. Montserrat for 1915 - 1916 Barbados, pp. 23 - 26.

Whitefield, F.G.S., 1933: The bionomics and control of Dysdercus (Hemiptera) in Sudan. Bull. ent. Res. 24(2): 301- 313.

Zile Singh and Purohit, M.L., 1972: A new record of an alternative host plant of the red cotton bug, Dysdercus cingulatus Fab. Indian J. Ent. 34(3): 256.